

The Laser Interferometer Space Antenna mission

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Abstract

The Laser Interferometer Space Antenna (LISA) mission is designed to detect and study low-frequency astrophysical gravitational radiation. The types of exciting astrophysical sources potentially visible to LISA include extra-galactic massive black hole binaries at cosmological distances, binary systems composed of a compact star and a massive black hole, galactic neutron star-black hole binaries, and background radiation from the Big Bang. LISA will also observe galactic binary systems which are statistically known to exist. Observation of these will provide strong verification of the instrument performance.

Gravitational waves are one of the fundamental building blocks of our theoretical picture of the universe. The effect of a gravitational wave passing through a system of free test masses is to create a strain in space that changes distances between the masses. However, gravitational radiation signals have not been directly measured. The main problem is that the relative length change due to the passage of a gravitational wave is exceedingly small. There is clear *indirect* evidence of the existence gravitational waves. The best example is from the binary pulsar PSR 1913+16. The binary system is losing energy at exactly the rate predicted by general relativity due to the emission of gravitational waves.

Several ground-based laser interferometers with arm lengths of several kilometers are now under construction. These km-size ground-based laser interferometers will be sensitive to gravitational waves at frequencies from ~ 10 Hz to ~ 1000 Hz. Ground-based detectors are expected to provide fundamental information about coalescing binary stars, the core collapse of supernovae events, and the distribution and properties of pulsars. However, ground-based detectors will always be limited to frequencies above 1 Hz due to the background of Newtonian gravity variations on the Earth which are indistinguishable from gravitational waves.

Space-borne detectors can open the low-frequency window to the universe for gravitational waves, where low-frequency refers to the frequency range 0.1 mHz to 1 Hz. This frequency range contains the only sources of gravitational waves that are both theoretically well-understood and known to exist in our neighborhood; the galactic neutron star binaries. The low-frequency gravitational radiation spectrum also contains the astrophysically most interesting sources. Only in the low-frequency range can the emission from massive black holes in the interior of galactic nuclei be observed.

LISA will detect gravitational wave strains down to a level of order 10^{-23} in one year of observation time by measuring the fluctuations in separation between shielded test masses located 5×10^6 km apart. The measurement will be performed by optical interferometry which determines the phase shift of laser light transmitted between the proof masses. Each proof mass will be shielded from extraneous disturbances (e.g. solar pressure) by the spacecraft in which it is accommodated. Drag-free control servos will be employed to keep each spacecraft precisely centered on test proof masses within it. The relative displacement between the spacecraft and test mass will be measured electrostatically and the drag compensation will be effected using proportional electric thrusters. The distances between test masses in different spacecraft will be measured by comparing transmitted and received laser beams between the spacecraft, forming a large Michelson interferometer.

LISA is a key element in the Structure and Evolution of the Universe theme within NASA's Office of Space Science. LISA has also been selected as a Cornerstone mission within the Horizons 2000 program of the European Space Agency. Plans are underway to pursue this mission as a joint NASA/ESA mission with launch near the end of the first decade of the new millennium. This paper will outline the LISA mission concept. The key technological hurdles will be presented along with the planned means to overcome them.